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Indian Standard

METHODS OF TESTING FUSION WELDED JOINTS IN ALUMINIUM AND ALUMINIUM ALLOYS

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METHODS OF TESTING FUSION WELDED JOINTS IN ALUMINIUM AND ALUMINIUM ALLOYS

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(*Continued on page* 20)

Indian Standard
METHODS OF TESTING FUSION WELDED JOINTS IN ALUMINIUM AND ALUMINIUM ALLOYS

0. FOREWORD

0.1 This Indian Standard was adopted by the Indian Standards Institution on 29 March 1974, after the draft finalized by the Welding General Sectional Committee had been approved by the Structural and Metals Division Council.

0.2 Standards relating to welded construction generally include the requirements of certain welding tests also. There is seldom any technical reason for the divergence in the welding test procedures, and there are practical and economic advantages in their standardization.

0.3 This standard covers the objective and procedure of various welding tests and recommends the requirements of test specimens in relation to welded construction in aluminium and aluminium alloys.

0.3.1 This standard does not purport to lay down the requirements regarding test plates, the selection of the tests, the specimens, the number of repeat tests and the criteria for acceptance. On these matters the relevant commonly accepted application standards may be followed, or they may be subject to agreement between the contracting parties.

0.3.2 Where differences exist among the commonly accepted application standards, the provisions of this standard are to be preferred.

0.3.3 The tests for fusion welds in aluminium and aluminium alloys should be selected on their own merits including their metallurgical aspects (*see* Appendix A). Since any comparison with those in other materials is not relevant.

0.3.4 It should be appreciated that any variation in the welding procedure and preparation of test specimens can affect the test results.

0.4 In the preparation of this standard due consideration has been given to the practices followed in this country. Also, assistance has been derived from the draft revision of BS : 3451 Methods of testing fusion welds in aluminium and aluminium alloys.

0.5 In reporting the result of a test or analysis made in accordance with this standard, if the final value, observed or calculated, is to be rounded off, it shall be done in accordance with IS : 2-1960*.

*Rules for rounding off numerical values (*revised*).

1. SCOPE

1.1 This standard prescribes the methods for testing fusion welds in aluminium and aluminium alloys.

1.2 Requirements for test plates, number of test specimens, mechanical test requirements and acceptance levels are not included. These are covered either in the appropriate application standard, or to be agreed to between the manufacturer and the purchaser.

2. DEFINITIONS

2.1 For the purposes of this standard, the definitions given in IS: 812-1957* shall apply.

3. RECOMMENDED TESTS

3.0 It is recommended that the welds are subjected to visual examination aided by dye or fluorescent penetrant methods.

3.1 The recommended destructive tests are:

a) *Butt Welds*
   1) Transverse tensile test,
   2) Examination of cross section (macro-examination),
   3) Side bend test,
   4) Transverse and longitudinal bend tests, and
   5) Nick-break test.

b) *Fillet Welds*
   1) Examination of cross section (macro-examination), and
   2) Fracture test.

4. VISUAL EXAMINATION

4.1 Object — The object of visual examination is to check the contour and soundness of the surface of the weld zone. The use of penetrant methods (*see* IS : 3658-1966†) is an aid to detecting flaws that would not be apparent under normal vision.

Visual examination is the primary method of weld examination and should always precede any other non-destructive or destructive testing.

4.2 Preparation — The weld shall be examined in the as-welded condition except that the surface to be examined shall be clean and free from any residues from the welding process.

4.3 Examination — The surface of the weld zone shall be examined visually with or without the use of a magnifier.

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*Glossary of terms relating to welding and cutting of metals.
†Code of practice for liquid penetrant flaw detection.

As a further aid to visual examination, one of the following types of penetrant methods (*see* IS : 3658-1966*) may be used:

a) A coloured dye which indicates flaws after treating the weld with developer.

b) A fluorescent penetrant which reveals its presence under a beam of ultraviolet radiation; treatment with a developer may or may not be used. This is less suitable than (a) for site inspection and requires particularly careful interpretation.

All residues from penetrant testing shall be removed to avoid contamination when further welding or repair welding is required.

4.4 Reporting of Results — The appearance and contour of the weld zone shall be described in the report, together with the nature and location of all flaws found. The use of any aid to examination shall be indicated in the report.

5. SEPARATION OF TEST SPECIMEN

5.1 The best method for separating the test specimens from the test piece is usually mechanical cutting, but when a specimen is sheared or thermally cut, adequate allowance shall be left for further machining. Any angular misalignment of welded test pieces shall be corrected cold before mechanical cutting, unless metallurgical conditions make this undesirable. To avoid localization of stress and premature failure, tool marks shall be minimized and shall run preferably parallel to the length of the specimens.

6. TRANSVERSE TENSILE TEST

6.1 Object — Used to determine the static tensile properties of a butt joint by assessing the soundness of the joint, or its performance under static stresses. The tensile test, besides measuring the static strength, shows the weakest zone. Sufficiently serious defects affecting the strength will be apparent on the fracture surface. It is a test used for experimental purposes for welder and procedure approval and for routine checks in production.

6.2 Preparation of Test Specimens — When the object of the test is to assess the performance of a structure as a whole, the weld shall be tested in the same condition as it would be in the actual structure. Where the object of the test is to assess the performance or soundness of a joint (as in comparing various procedures and in welder approval) and when the parent metal is thicker than 2 mm, excess weld metal and penetration bead shall be removed.

6.3 Test specimens shall follow one of the forms shown in Fig. 1 and 2 and shall be of the dimensions shown in Table 1. Parallel specimens shall be

*Code of practice for liquid penetrant flaw detection.

used only in the cases when the strength of the weld zone is likely to be less than that of the unaffected parent metal.

6.3.1 When the thickness of the material exceeds 30 mm, several specimens representing the full thickness of the joint may be cut as shown in Fig. 3. Each specimen shall have a thickness at least 30 mm and a width, *b*, at least 40 mm.

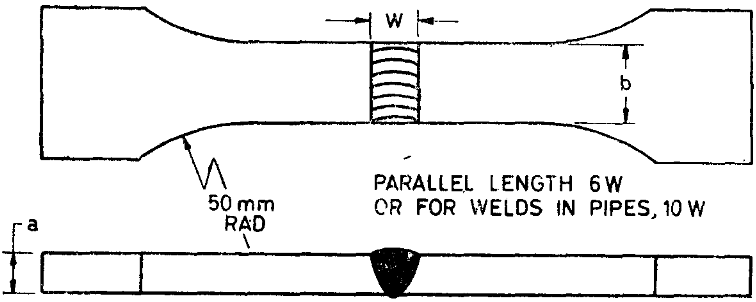


FIG. 1 REDUCED TRANSVERSE TENSILE TEST SPECIMEN

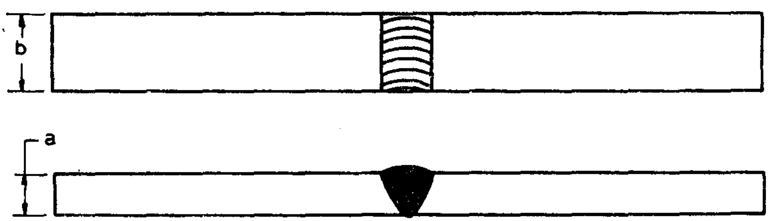
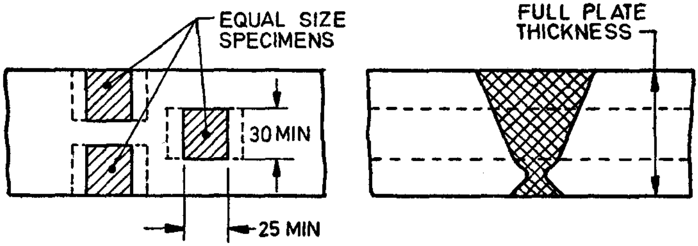


FIG. 2 PARALLEL TRANSVERSE TENSILE TEST SPECIMEN



All dimensions in millimetres.

FIG. 3 METHOD OF CUTTING SEVERAL TRANSVERSE TENSILE TEST SPECIMENS FROM FULL PLATE THICKNESS

6.4 Shouldered specimens shall be produced only by blanking if excess weld metal has been removed previously. The edges of the reduced parallel portion shall be finished by machining or draw filing. Specimens to be tested with excess weld metal and penetration bead left intact shall be produced by machining. The length of the parallel part of shouldered specimens or the length between grips of parallel specimens shall be not less than 6 *W* where *W* is the width of the weld.

The gauge length shall be symmetrically disposed about the centre line of the weld.

TABLE 1 DIMENSIONS OF TRANSVERSE TENSILE TEST SPECIMENS

(*Clause* 6.3)

Thickness of Material		Width of Specimen
Over	Up to and Including	
mm	mm	mm
—	3	12
3	10	20
10	20	26
20	30	40

6.5 Alignment of Joint Members

6.5.1 The linear misalignment *m* of the two members of the welded joint as shown in Fig. 4, shall not exceed the value given in Table 2 before testing.

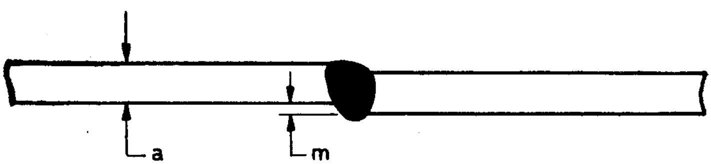


Fig. 4 Linear Misalignment

TABLE 2 MAXIMUM LINEAR MISALIGNMENT IN TRANSVERSE TENSILE TEST SPECIMENS

(*Clause* 6.5.1)

Thickness of Material		Linear Misalignment (m)
Over	Up to and Including	
mm	mm	mm
1·6	3	0·25
3	6	0·40
6	30	0·50

Note 1 — When the thickness of the material does not exceed 1·6 mm special precautions may be necessary.

Note 2 — It is recognized that the existing pipe tolerances may make compliance with this table very difficult, but this should not be regarded as sufficient reason for rejecting test specimens.

6.6 The angular misalignment α of the two members of the welded joint as shown in Fig. 5, shall not exceed the values given in Table 3 before testing.

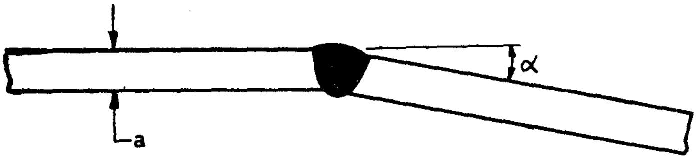


FIG. 5 ANGULAR MISALIGNMENT

TABLE 3 MAXIMUM ANGULAR MISALIGNMENT IN TRANSVERSE TENSILE TEST SPECIMENS

(*Clause* 6.6)

Thickness of Material		Angular Misalignment
Over	Up to and Including	(α)
mm	mm	degrees
—	1·6	10
1·6	30	5

NOTE — Linear and angular misalignment can be measured easily by suitably shaped templates.

6.7 Testing — The specimens shall be tested in tension in accordance with IS : 1816-1961*. When the 0·2 percent proof stress is required, a gauge length of 50 mm shall be symmetrically disposed about the centre line of the weld.

6.8 Reporting the Test Results — The following shall be reported as test results:

a) When required, the value of 0·2 percent proof stress.

b) Tensile strength, calculated from the maximum load and original cross-sectional area. When the specimen is machined all over, the cross-sectional area shall be taken as the actual cross-sectional area after machining. When excess weld metal and penetration bead are not removed, the cross-sectional area shall be the product of the thickness of the parent and the width of the specimen.

c) Location of the fracture, as to whether it is in the weld, in the heat-affected zone or in the parent metal. If fracture occurred

*Method for tensile test for light metals and their alloys.

in the parent metal, its approximate distance from the weld junction. (The weld width shall also be quoted.)

d) Type and location of any weld flaws on the fractured surface.

e) Whether excess weld metal and penetration bead were removed or not, the amount of correction of angular and linear misalignment, if any.

f) If required, the measured elongation, and the gauge length.

NOTE — If any elongation values are quoted, they should be expressed as a percentage of the gauge length. Attention is drawn to the fact that elongation values are comparable only for similar specimens of the same thickness and the results obtained with specimens of different thicknesses are not comparable.

7. EXAMINATION OF CROSS SECTION

7.1 Object — The object of macro-examination of suitable cross sections is to check the soundness of a welded joint and this examination is useful in the quality control of welding. Apart from being used to investigate the origin of defects, examination of an etched macro-section enables the checking of the joint design, the number of runs and the extent of parent metal and inter-run fusion.

7.2 Preparation of Test Specimen — The specimen shall be of the full thickness of the material at the welded joint and the excess weld metal and penetration bead shall be left intact. The specimen shall contain a length of the joint of approximately 10 mm, and shall extend on each side of the weld over a distance that includes the heat-affected zone and some parent metal (*see* Fig. 6).

7.2.1 The specimen shall be prepared, polished and etched using an approved method and etching solution (*see* Appendix B).

7.3 Reporting the Test Results — After visual examination a full description of the appearance of the surface and the type and location of any weld flaws shall be reported. If necessary a magnifying glass of magnification 5 may be used for the usual examination.

8. SIDE BEND TEST (FOR MATERIAL OF THICKNESS 10 mm AND OVER)

8.1 Object — The object of the side bend test is to determine the soundness of the weld in the cross section. It will reveal the unsoundness at the mid-section which is not likely to be observed in transverse and longitudinal bend test.

8.2 Preparation of Test Specimen — The shape and dimensions of the test specimen shall be in accordance with Fig. 7 and the edges of the specimen shall be rounded to a radius not exceeding 10 percent of the thickness of specimen. The length of the specimen shall be such that it will satisfy the specified requirements.

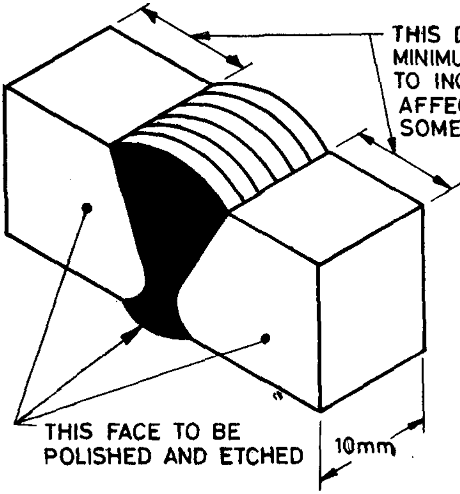
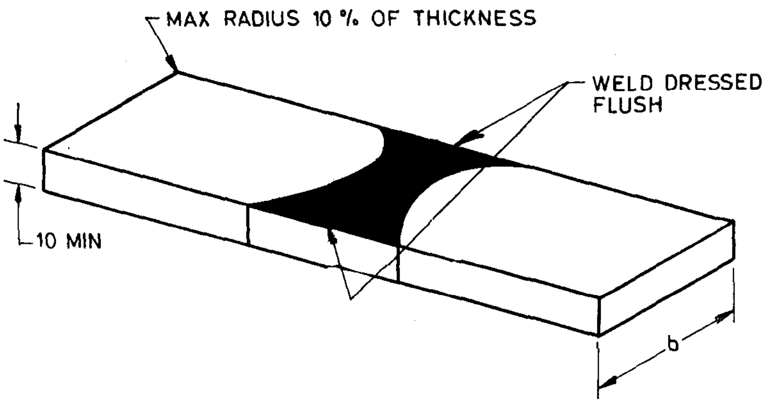


FIG. 6 TEST SPECIMEN FOR MACRO-EXAMINATION



All dimensions in millimetres.

FIG. 7 SIDE BEND TEST SPECIMEN

The width *b* of the test specimen shall be of the full thickness of the material at the welded joint, and the excess weld metal and penetration bead shall be dressed flush with the original surface of the material.

8.3 Testing — The specimen shall be bent through 180° so that a face of the weld cross section is in tension, using the type of controlled bend test apparatus shown in Fig. 8.

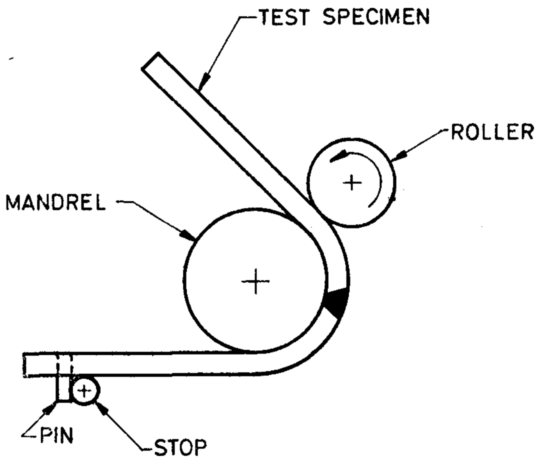


FIG. 8 SCHEMATIC DIAGRAM OF CONTROLLED BEND TEST APPARATUS

8.4 Reporting the Test Results — The following shall be reported as test results:

a) Width and thickness of the specimen;
b) The radius of bend expressed as a multiple of the thickness of specimen;
c) The amount of correction of angular misalignment, if any; and
d) Appearance of joint after bending, for example, type and location of any flaws.

9. TRANSVERSE AND LONGITUDINAL BEND TEST

9.1 Object — The object of the transverse and longitudinal bend tests is to determine the soundness of the weld metal, weld junctions and heat-affected zone (that is, weld zone) when the side bend test or the transverse tensile test are not practicable. They are, therefore, of limited usefulness.

The transverse bend test may be used to reveal root flaws, particularly in butt welds in pipes. The longitudinal bend test may be used to determine whether the weld has sufficient capacity for plastic deformation in subsequent fabrication operations; it is not applicable to welds in pipes.

9.2 Preparation of Test Specimen — The test specimen shall be of the full thickness of the material at the welded joint. The excess weld metal

and penetration bead shall be dressed flush with the original surface of the material, except that in the transverse bend test which is used to reveal the root flaws in butt welds in pipes, the penetration bead shall be left intact.

The width of the test specimen shall be the same as *b* given in Table 1 and the length shall be such that it will satisfy the specified test requirements. The edges of the specimen shall be rounded to a radius not exceeding 10 percent of the thickness of specimen.

9.3 Testing — The specimen shall be bent through 180° so that the root of the weld or the weld face is in tension in a transverse or longitudinal direction, as applicable (*see* Fig. 9 and 10) using the type of controlled bend test apparatus shown in Fig. 8.

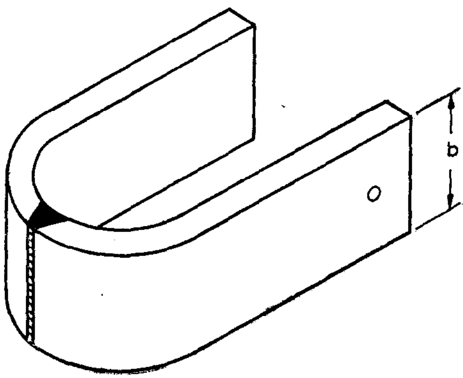


Fig. 9 Transverse Bend Test Specimen After Bending

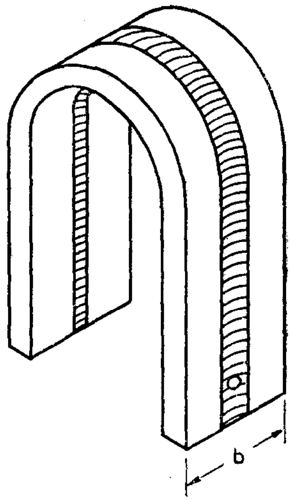


Fig. 10 Longitudinal Bend Test Specimen After Bending

9.4 Reporting the Test Results — The following shall be reported as test results:

a) Width and thickness of the specimen;
b) Direction of bend (transverse or longitudinal) and which surface was in tension;
c) The radius of bend expressed as a multiple of the thickness of specimen;
d) The amount of correction of angular misalignment, if any; and
e) Appearance of joint after bending, for example, type and location of any flaws.

10. NICK-BREAK TEST (FOR MATERIAL OF THICKNESS 10 mm AND OVER)

10.1 Object — The nick-break test is sometimes used for assessing the presence of weld defects. However, it will show, only those defects immediately adjacent to the notch, such as uniformly distributed porosity. On account of this it is of limited usefulness, and, therefore, this test is not recommended for welds in the grades of pure aluminium and in alloy N3 due to high ductility of these materials.

10.2 Preparation of Test Specimen — The test specimen shall be cut transversely to the welded joint and shall be of the full thickness of the material at the joint. The excess weld metal and penetration bead shall be left intact. The width of the test specimen shall be the same as given in Table 1. A saw-cut shall be made in each cross-sectional face of the weld along the weld centre line (*see* Fig. 11). The depth of each saw-cut shall be approximately 10 percent of the specimen thickness.

10.3 Testing — The specimen shall be fractured along the centre line of the weld by bending or by blows (*see* Fig. 11).

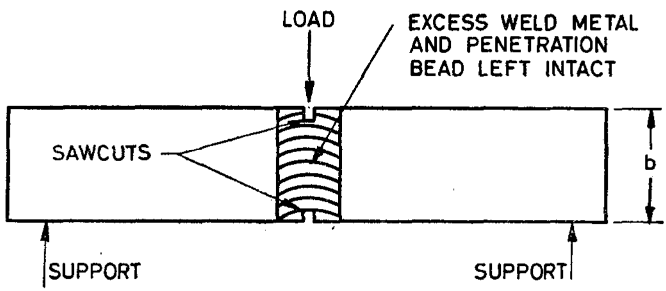


FIG. 11 METHOD OF FRACTURING NICK-BREAK TEST SPECIMEN

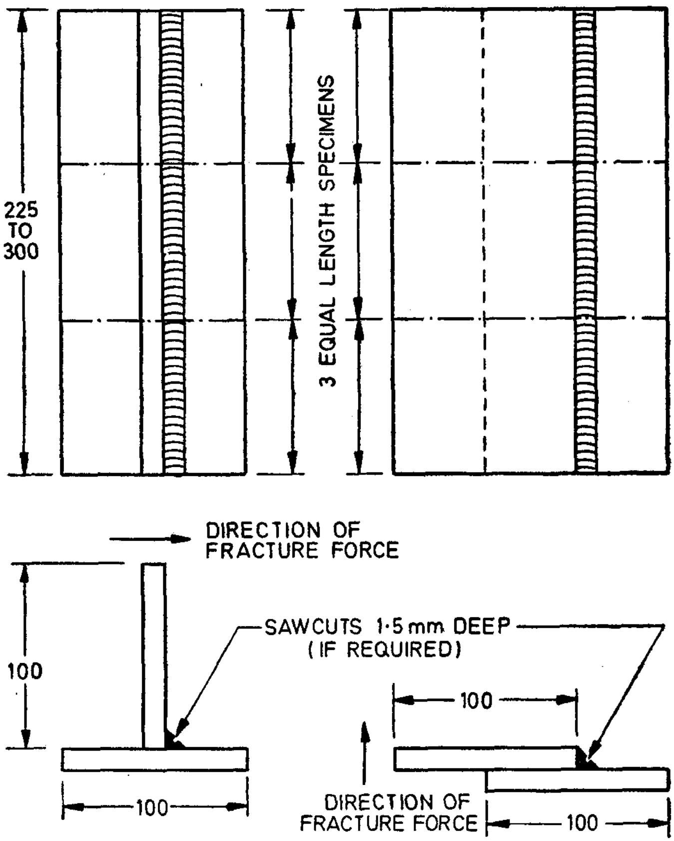
10.4 Reporting the Test Results — A full description of the appearance of the fractured surface and the type and location of any weld flaws shall be reported.

11. FILLET WELD FRACTURE TEST (FOR MATERIAL OF THICKNESS 3 mm AND OVER)

11.1 Object — The fracture test on fillet welded joints is intended to reveal the depth of penetration and the presence of root defects. When used on high ductility materials fracture may not occur, particularly on thin material.

11.2 Preparation of Test Specimen — The test specimen shall be prepared in one of the forms shown in Fig. 12. To ensure fracture in the weld a central saw-cut 1·5 mm deep may be made along the length of the weld face.

11.3 Testing — The specimens shall be fractured by bending or by blows applied in the direction shown in Fig. 12.



All dimensions in millimetres.

FIG. 12 ALTERNATIVE FORMS OF FILLET WELD TEST PIECE AND SPECIMEN

11.4 Reporting the Test Results — The following shall be reported as test results:

a) Thickness of parent metal;

b) Throat thickness and leg length of weld;

c) Location of fracture; and

d) Appearance of joint after testing, for example, type and location of any flaws.

APPENDIX A

(*Clause* 0.3.3)

METALLURGICAL ASPECTS OF TESTING WELDS IN ALUMINIUM

A-1. NON-HEAT-TREATABLE ALLOYS

A-1.1 Pure aluminium and a number of its alloys (for example, those with the prefix N in IS : 733-1967*, IS : 734-1967†, IS : 736-1965‡, IS : 737-1965§, IS : 738-1966||, IS : 739-1966¶ and IS : 740-1966**) are termed non-heat-treatable because they can be hardened only by cold working. The application of heat, as in fusion welding, causes little change to the structure and mechanical properties of such materials when they are in annealed condition, but work-hardened metal is softened adjacent to the weld. Some forms of these wrought materials, such as plate and extrusions, are supplied in the 'as manufactured' condition. Generally they will be work-hardened to a slight extent and, therefore, will be softened locally by the heat of the welding process. Figure 13 shows the different zones in such a welded joint and indicates the pattern of the expected variation in hardness.

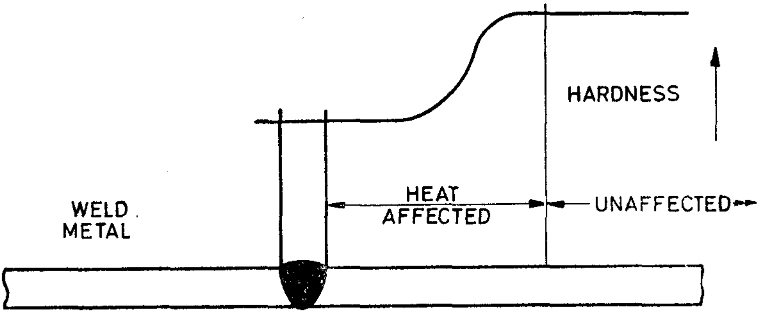


FIG. 13 WELD ZONES IN NON-HEAT-TREATABLE ALLOYS

* Wrought aluminium and aluminium alloys, bars, rods and sections (for general engineering purposes) (*first revision*).

† Wrought aluminium and aluminium alloys, forging stock and forgings (for general engineering purposes) (*first revision*).

‡ Wrought aluminium and aluminium alloys, plate (for general engineering purposes) (*revised*).

§ Wrought aluminium and aluminium alloys, sheet and strip (for general engineering purposes) (*revised*).

|| Wrought aluminium and aluminium alloys, drawn tube (for general engineering purposes) (*revised*).

¶ Wrought aluminium and aluminium alloys, wire (for general engineering purposes) (*revised*).

**IS Wrought aluminium and aluminium alloys, rivet stock (for general engineering purposes) (*revised*).

A-1.2 Welded joints in pure aluminium and non-heat-treatable alloys are generally made with filler metal of the same nominal composition as the components to be welded without the addition of filler metal. Because of the structural difference between the cast and the wrought metals, the strength and ductility of the weld metal are usually slightly less than those of the annealed wrought components. In the case of alloys N4 and N5, a filler material of higher magnesium content (for example, NG6) is usually employed to minimize the risk of weld cracking during solidification, and in such instances the weld metal can be stronger than the annealed parent material.

A-1.3 Associated with the differences in structure and, possibly, composition which may exist across fusion welded joints in these materials, there are differences in the mechanical properties. The values obtained for conventional proof stress and percentage elongation will be rather variable, being determined by the width of the softened region (that is, by the welding conditions) as well as by the initial temper. Because of the heterogeneous nature of the joint it should be appreciated that a proof stress determination cannot easily be compared with those of welds in different thicknesses and alloys. For the same reason the elongation measurements should always be quoted as a percentage of a specified gauge length. Elongation values should be considered in relation to both tensile strength and location of fracture. Low elongation, coupled with weld metal failure, does not usually mean brittle weld metal. It is more likely to indicate low strength weld metal or the presence of defects. Generally the elongation value increases with increase in tensile strength of the joint. The parallel portion of a tensile test piece should be sufficiently long to include the heat affected zone. Generally a parallel length six times the width of the weld is sufficient for the purpose. Variations in the width of the softened region will also affect bend tests on butt welds, particularly those made with the axis of the bend parallel to the direction of the weld. When a weld in work-hardened material is subjected to a bend test, this should be of the controlled type to ensure that the specimen conforms to the mandrel, otherwise 'peaking' will occur and the strain will be concentrated in the weakest point (which will either be the weld or heat-affected zone) to such an extent that premature failure may occur. It is for this reason that the free bend test is not recommended. A joint of similar quality in annealed material of the same composition would bend satisfactorily because the strain would be distributed more uniformly between the weld metal or the heat-affected zone and the surrounding material.

When sound joints in annealed pure aluminium or non-heat-treatable alloys welded with filler metal of the same nominal composition are tested in tension with excess weld metal left on, the point of failure will be either at the edge of the weld or at some distance away from the weld. When excess weld metal is removed, failure is most likely to occur within the weld metal. In the case of sound welds in work-hardened material, failure will

occur at the edge of the weld when excess weld metal is left on, and in the weld metal when excess weld metal is removed.

A-2. HEAT-TREATABLE ALLOYS

A-2.1 A number of aluminium alloys are described as 'heat-treatable' (for example, those with the prefix H in IS : 733-1967*, IS : 734-1967†, IS : 736-1965‡, IS : 737-1965§, IS : 738-1966||, IS : 739-1966¶, and IS : 740-1966**) because, though they can be hardened somewhat by cold working, they are normally and more effectively hardened by heating to a temperature range 450-540°C depending on the composition and quenching, and then ageing either at room temperature or at a temperature usually in the range 100-200°C. Fusion welded joints in these materials are often made with filler metal of significantly different composition to achieve freedom from weld cracking and also to ensure adequate strength, though they are occasionally made without the addition of filler metal.

A-2.2 In most cases, the weld metal age hardens on keeping and thus becomes stronger than the over-aged material in the heat-affected zones shown in Fig. 14. Hence, when joints in these materials are tested in tension

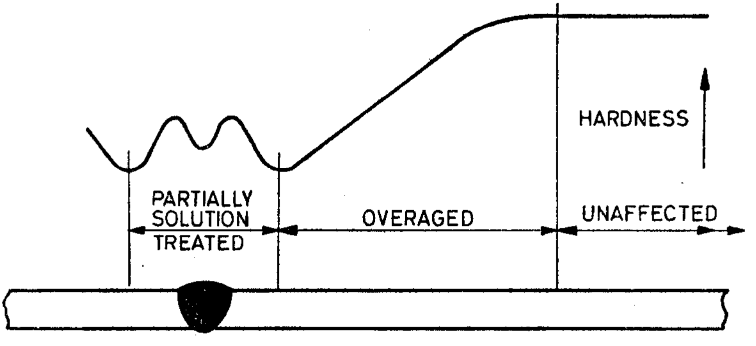


FIG. 14 WELD ZONES IN HEAT-TREATABLE ALLOYS

* Wrought aluminium and aluminium alloys, bars, rods and sections (for general engineering purposes) (*first revision*).

† Wrought aluminium and aluminium alloys, forging stock and forgings (for general engineering purposes) (*first revision*).

‡ Wrought aluminium and aluminium alloys, plate (for general engineering purposes) (*revised*).

§ Wrought aluminium and aluminium alloys, sheet and strip (for general engineering purposes) (*revised*).

|| Wrought aluminium and aluminium alloys, drawn tube (for general engineering purposes) (*revised*).

¶ Wrought aluminium and aluminium alloys, wire (for general engineering purposes) (*revised*).

** Wrought aluminium and aluminium alloys, rivet stock (for general engineering purposes) (*revised*).

in the 'as welded' condition with excess weld metal left on, failure usually occurs some distance away from the weld; with sound weld metal this may also occur when excess weld metal is removed. However, the precise position of the failure, the proof stress, the tensile strength and the ductility of the joint will depend upon the extent of the softening produced, which is governed principally by the welding conditions and the thickness of the material for a given alloy. When 'as welded' joints in heat-treatable alloys are subjected to bend tests which permit 'peaking', bending will be concentrated in the softened regions of the heat-affected zones. The strength of joints in the heat-treatable alloys may largely be recovered by complete re-heat-treatment after welding, but the ductility of the weld metal will be somewhat less than that of the wrought material away from the weld. It should be noted that it is particularly important to keep angular and linear misalignment to a minimum in heat-treatable alloys to prevent non-uniform loading while performing tensile tests in welds.

APPENDIX B

(*Clause* 7.2.1)

SUGGESTED METHOD OF PREPARING ETCHED SPECIMENS

B-1. PREPARATION OF SURFACES FOR ETCHING

B-1.1 The initial preparation of a cut surface may be by milling or turning. Alternatively, the surface should be filed with a coarse file until all deep marks are removed. It should then be filed at right angles to the original coarse file marks with a smooth file. The application of chalk to the teeth of the fine file will reduce the risk of surface scoring by metallic particles trapped in the teeth of the file.

The machined or smooth-filed surface is then abraded on successively finer grades of waterproof silicon carbide paper. A suitable sequence of grit sizes is 100, 240, 400 and 600. If the specimen is of suitable size to handle conveniently, the most satisfactory procedure is to lay the appropriate sheet of abrasive paper, face up, on a flat surface, such as plate glass, resin-impregnated paper laminate, etc. The abrasive paper is then lubricated with water, industrial alcohol, or white spirit, and the specimen is carefully rubbed on it, applying moderate pressure, until all traces of the surface scratching from the previous treatment are removed. The specimen is washed to remove all traces of the abrasive. The procedure is repeated with the next finer grade of abrasive paper, the direction of abrading in each case being at right angles to the marks made by the previous paper.

In the cases where the specimen size is such that the above procedure is

inconvenient, the abrading may be carried out by employing rotating abrasive discs in a suitable hand tool. This operation will of necessity be carried out dry, and successively finer grit sizes should be used. Care should be taken to avoid exerting undue pressure on the surface, since this will cause metal to flow over, and obscure any fine porosity which may be present.

A fine-machined surface, produced by sharp tools, with adequate lubrication, is suitable for macro-etching without any further preparation, and the abrading of a filed surface need only be taken as far as 400 grade for a satisfactory etch. Such machined surfaces are not, however, in the most suitable condition for the detection of fine porosity, for which purpose it is recommended that abrading down to 600 grade paper should be employed.

B-2. ETCHING FOR MACRO-EXAMINATION

B-2.1 Two suitable etching solutions for welds in pure aluminium and all wrought alloys are the following:

a) 45 percent by volume of hydrochloric acid ($d=1\cdot16$)
   15 percent by volume of nitric acid ($d=1\cdot42$)
   15 percent by volume of hydrofluoric acid (40% m/n HF)
   25 percent by volume of water

b) 10 percent by volume of nitric acid ($d=1\cdot42$)
   2 percent by volume of hydrofluoric acid ($d=1\cdot16$)
   88 percent by volume of water

Etching is carried out either by swabbing with cotton wool or by immersion. After this treatment wash the specimen in water, blot the surface with filter paper and dry in warm air.

(*Continued from page* 2)

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3600-1973 Methods of testing fusion welded joints and weld metal in steel (*first revision*)

4943-1968 Assessment of butt and fillet fusion welds in steel sheet plate and pipe

7307 (Part I)-1974 Approval tests for welding procedures, Part I Fusion welding of steel

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